From The Machine Learning Region to The Deep Learning Region: Tesla, DarkTrace and DeepMind as Internationalised Local to Global Cluster Firms

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**Abstract**

In this chapter we explore how cluster internationalisation evolved through a process called co-presencing. We further take into account key areas where proposed 4.0 Economy processes are likely to cause major disruption to established business models (including cluster models). Key here is the rise of artificial intelligence (AI) and its application in production and services. We take as illustrations three vignettes based on AI learning applications. In particular we differentiate Machine-Learning from Deep-Learning regions. This leads to accounts of changed aspects of the spatial configurations entailed, as described in the first main section of the chapter. Thereafter, the rest of the chapter collects answers to questions about whither cluster internationalisation seems to lead. We briefly review exemplary research literature on “co-presencing” or multi-scalar clustering of global-local knowledge intensive production and services interactions. This begins in the second section of the chapter, which references issues of “co-presencing” at localised cluster scale. Then, in the third section attention moves into issues of internationalisation by diagonal and lateral cluster-to-cluster interaction at the global scale. Finally, conclusions are drawn.

**Introduction**

In this chapter we explore how cluster internationalisation evolved through a process called co-presencing. We further take into account significant change that has either occurred or is expected to occur under the influence of the rise of the Quaternary or 4.0 Economy and especially the 4.0 Web as described by Evans and Forth (2015). One of the key areas in which 4.0 processes are likely to cause major disruption to established business models (including cluster models) is the rise of artificial intelligence (AI) and its application in production and services. Central to this automation information platform are two variants of AI that can be seen or inferred to presage different applications, implications and economic-geographic effects. We are interested in all three of these, but especially in the third, which has had no visible impact in the economic geography research literature thus far.

So this chapter is by way of a review of cluster-to-cluster traditions that have emerged in the 1990-2020 era of “lean production”, “open innovation” and globalised knowledge flows and exploitation. Why? Because there is evidence in some influential exemplars that 4.0 economic organization is in the process of reversing some of the most hard-learned lessons of the Post-Fordist era. The chapter is constructed in three sections. First is a set of three vignettes that are based on AI learning applications and accounts of some aspects of the spatial configurations entailed. Most striking of these is the way electric vehicle (EV) innovator Tesla has inverted many Post-Fordist norms by AI applications. Two further vignettes briefly examine changing business model perspectives and local-to-global cluster co-presencing in which very large AI-application firms grow from small-to-large scale by endogenous AI cluster growth or penetration into such endogeneity contexts by “space-invader” acquisition and adaptation of dynamic AI innovators. In all these cases the two types of learning are finding “related variety” niches in wholly new markets such as EVs, batteries, security and healthcare.

To set the scene we define the “learning” field of interest according to the following distinction. Machine learning uses algorithms to parse data, learn from that data, and make informed decisions based on what it has learned. Deep learning structures algorithms in layers to create an “artificial neural network” that can learn and make intelligent decisions on its own. Deep learning is a subfield of machine learning. Finally, the bulk of the chapter collects answers to questions about whither cluster internationalisation is widely understood to operate according to a wide range of leading research literature on “co-presencing” or multi-scalar clustering of global-local knowledge intensive production and services interactions (Cooke, 2019). These are separated into two collections of issues. Successively, the research is first focused on cluster-originated interactions, notably highlighting Cambridge’s high tech cluster-platform and aspects of London’s new knowledge “hub”. This then moves from the second section, which references issues of “co-presencing” at localised cluster scale that, in the third section moves into issues of internationalisation by cluster-to-cluster interaction at the global scale. Much of our interest is expressed in the exploration and exploitation of Quaternary or 4.0 Economy innovation and the spatially uneven origins of such “knowledge economy” resources.

**1. Agents and Mechanisms of Cluster Internationalisation: Post-Fordism in Question.**

We begin this brief empirical section by explaining the different ways in which cluster-to-cluster and cluster-supercluster embedding occurs. “Superclusters” are locations of very large suppliers of parts and components or –especially – design services like EV powertrains and batteries or smartphone “chipsets”, also cloud computing, data centres and much of the infrastructure of 4.0 economy output. Shenzhen, Shanghai and Beijing in China have the full set, while New Jersey’s “digital donut” and London’s “digital alley” combine automated trading system (ATS) data centres with giant Amazon “fulfillment centres” driven by “chaos storage” AI (Cooke, 2019).

We now reference Belussi’s (2018) review categorising three evolutionary cluster phases: “early”, “development” and “mature”. In the first cluster phase MNCs effectively created clusters or successful cluster firms grew rapidly to reach MNC scale (Storper & Harrison, 1991, in the first instance; Bellandi, 2001, in the second). In the development phase, the cluster embeds the MNC by virtue of learned and valuable cluster competences or the MNC makes strategic acquisitions of indigenous cluster incumbents (Chen, 2008; Biggeiro, 2002). Finally, multi-scalar co-presencing (Cooke, 2019) is also found in the cluster maturity phase. Here, the “release” stage of cluster evolution is reached with a declining rate of cluster growth but indigenous MNCs have emerged while innovation occurs in some peripherally co-presenced global innovation networks (GINs; Cooke, 2013), knowledge-based acquisitions of indigenous kingpin firms occur (Oliver et al, 2008) or, finally, clusters are eviscerated by external control, including by financialisation (Mason & Harrison, 2006; Østergaard & Park, 2015; Isaksen, 2018).

The illustrations are of one textured vignette for each: first is the case of Tesla for “early” with new, local cluster formation (2017-onwards) succeeding initial cluster-to-cluster linkage from Silicon Valley to the Michigan auto-cluster (2003-onwards). Machine-learning is pronounced in plant organisation (notably bespoke in-house enterprise resource planning) (ERP), vertical integration (battery “gigafactory”) and customised technical upgrades. Darktrace is an exemplar of cluster “development”, being a spinout of a local, endogenous “born global” multinational – Cambridge data-miner Autonomy, acquired by cluster-to-cluster (Silicon Valley-Cambridge, UK) Hewlett Packard. It utilises machine learning modeled on the human immune system to facilitate its core competence in cybersecurity. Finally, DeepMind, also a cluster-to-cluster (Silicon Valley-Canada-UK) acquisition by Google that uses “deep learning” in its healthcare data analytics, having out-performed humans in artificial intelligence (AI) contests versus chess and “Go” champions.

*Tesla*

Tesla is a cluster-platform beneficiary of the latest thinking in configuration of the world’s leading electric vehicle (EV) supply chain at its Fremont, California plant, eighteen miles from Tesla HQ in Silicon Valley. The lessons for value chain analysts and strategists, regardless of industry or location, are evident and “disruptively” reverse outsourcing principles that have predominated for decades. One of the first noticeable features is Tesla’s commitment to home-based production organisation, in line with, but predating since 2003, the Trump 2016 administration’s “Made in America” mantra. Thus contrary to conventional wisdom about low-cost labour manufacturing locations, Tesla produces its cars in California. This contradicts, for example, what established automobile company Ford is constructing, which is a new $1.6 billion factory in Mexico. In fact, Tesla’s plant location is home of not only some of the best-paid ICT automotive technical talent in the world, also the most expensive wages and real estate anywhere. This arises from Tesla’s extraordinary amount of investment in advanced robotics, most of which is designed for flexibility and interaction with several thousand workers on the shop floor. Extremely high sale prices have helped this tactic, but the 2016 explosion of pre-orders for some 300,000 Model 3s for $35,000 each rests on the premise that affordable cars can be made in the U.S., so long as the end-to-end value chain is designed for growth.

Outsourcing of manufacturing parts and components was a natural result of core competence-oriented business strategies in vogue during the 1990s. This was designed into NAFTA (subsequently rescinded in favour of on-shoring) and the rise of Chinese manufacturing, which was also crucial to the outsourcing business model. “Lean production” meant the basic idea was to become asset light by undoing much of the vertical integration left over from the Fordist era in Detroit. Tesla is rapidly going the other way. Tesla’s initial cluster-to-cluster supply chain belies its location in Silicon Valley since most of its suppliers are in the US car cluster in Michigan (locations like Southfield, Troy (2), Zeeland, Plymouth (2), Ypsilanti, St Clair Shores and Detroit). A few others are in nearby Wisconsin (Racine), Indiana, Illinois and over the border in Canada (3, including 2 Magna). Elsewhere, Germany has suppliers like ZF Lenksysteme-Bosch, ADAC and Stabulus, while Japan, Kanagawa (2), and Hitachi Cable (Indiana) and Panasonic (Chicago and San Jose, CA) are in the US. Other single supplier locations include Switzerland, Italy, The Philippines, China and Spain.



**Fig. 1. Tesla Model S Suppliers, 2013**

Source: Supplier Business

Tesla’s strategic architecture resembles aspects of Apple store and digital marketing; Tesla is positioned to perpetually sell new capabilities to existing customers. These include not only information features like gauges, GPS enhancements or entertainment systems but also physical add-ons like speed, braking and further in-car entertainment.  This is how Tesla simulates selling a giant iPhone. Accordingly, while the Fremont facility is a full-service assembly plant, Tesla’s short-term plans include a supplier park built in the immediate plant vicinity with a focus on large, heavy parts with extensive variations. Taking integrated manufacturing still further, Tesla has also built a giant battery factory in nearby Nevada. The battery plant assembles elemental raw materials like copper and aluminium and produces finished battery packs to supply the car plant (quasi-Fordism). Tesla seems to have more problems with software than hardware. By 2013 Tesla had taken the in-sourcing decision hitherto typically outsourced to the likes of SAP (Tesla replaced SAP ERP in 2015) or Oracle by building a bespoke ERP system in-house to be more agile, rather than conforming to the traditional Buy-and-Configure method. This design strategy arose following a decade-long war between the aforementioned giant ERP vendors. For example, Oracle’s strategy rests on an infrastructure stack from silicon to screen enabling a cloud-based future for business. Its aim is winning the “mega-cloud” race and leveraging it for supply chains that are faster, cleaner, cheaper and closer to the customer. In response to advisers’ warnings about trying to scale a home-grown, light-weight ERP system, Elon Musk delegated the responsibility to his former CIO Jay Vijayan who had figured the homegrown ERP system would scale effectively. Tesla’s strategy plans massive upscaling of production running on Microsoft Azure Cloud operating with Scala Language, based on “Ruby on Rails”. SAP and Oracle's offerings were not "cloud-native applications." So SAP or Oracle would take a year at least while the in-house solution took four months. Musk realised that Vijayan would build what Tesla needed, not what the industry deemed appropriate (O’Marah, 2016; Bedigan, 2015, Mendix, 2013).

Leaving nothing to chance, Tesla also continues to invest in a network of supercharger stations around the US to ensure customers have a functional alternative to the traditional refuelling stations. Finally, Tesla is pioneering the practice of shipping product digitally rather than physically. Tesla customers monitor the instrument panel, a massive navigation screen and even engine control algorithms that update over the cloud automatically whenever the company distributes a new digital service direct to the moving vehicle. Having designed the vehicle from the ground up as a hybrid of mechanical technology and digital technology, Tesla is positioned to perpetually sell new capabilities to existing customers.

*Darktrace*

Duke, S. (2018) explains how this Cambridge Cybersecurity cluster firm raised $50 million for its internationalisation drive. This makes it one of the UK’s most valuable technology start-ups. The latest valuation of Darktrace reached some $1.65 billion ($499 million more than at the end of May 2018 four months earlier). The investment round was led by Vitruvian Partners a private equity firm in partnership with KKR, the American investment group. This fundraising coincides with growing demand by companies and governments worldwide for protection against cyberattacks. New EU Data Processing rules oblige weakly protected firms or governments to strengthen their defences or face huge fines (up to 4% of turnover) for mishandling customer information. Darktrace uses machine learning and AI tools to alert clients if their systems have been infiltrated. The model is based on human immune system defences against bacteria or viruses The software learns patterns of normal computer network behaviour. This enables algorithms to spot anomalies rather than preventing breaches. Instead they stop identified breaches from escalating to a dangerous level.

Darktrace was founded with investment from Invoke Capital, a fund created by Michael Lynch when he sold data-mining firm Autonomy to Hewlett Packard for $8 billion in 2011. Since its founding, Darktrace in 2013 has harnessed expertise from the UK Secret Intelligence Service. One of its co-founders is a former employee of MI5 and its first CEO was a former deputy director of cyberdefence at GCHQ. Clients of Darktrace include Drax, the renewable power generating station, Gatwick Airport, AIG insurance and Aegon Sony Life Insurance. Darktrace has raised $230 million since its launch. It has 33 offices worldwide, including Los Angeles, Mexico City and Sao Paulo. Its Enterprise Immune System (EIS) defeat devices are deployed in 2000 networks with contracts worth $400 million. It has 800 employees, most in Cambridge and Singapore. Darktrace intends to expand globally, notably in Latin America and Asia. It is in debt because of investing heavily in building up the customer base, In the year to end-June 2017 revenues rose 80% to $35 million. Operating losses worsened to $30 million from $13 million in 2016. Vitruvian summarised its investor perception that Darktrace has world class AI capabilities, deep cyber-domain expertise and a highly effective business model.

*DeepMind*

As traditional markets slowly discover the advantages of Quaternary (4.0 Economy) business systems the “flagship” cloud, AI machine learning and deep learning, and Big Data analytics firms like Facebook, Apple, Google, Amazon and Microsoft (FAGAMi) have homed in on the healthcare sectors of the advanced economies, many of which are seriously underinvested in such platforms. Global AI investment in manufacturing by 2017 was 83% compared to only 23% in healthcare. Thus since 2014 Apple made the following healthcare acquisitions or “star scientist” recruitments (Table 1). IBM is

**Date Acquisition Date Acquisition/Recruitment**

**2014 – HealthKit; Gorilla healthcare (AI) 2017 – Gliimpse (acq. AI engine)**

**2015 – ResearchKit (AI CRO) 2017 – Beddit (acq. Sleep tracking)**

**2016 - CareKit (App Algo) 2017 – ClickWell Care (hires CEO Desai)**

**Table 1: Apple Healthcare Acquisitions and Recruitments 2014-2017**

**Source: Author**

another “Big Healthcare” investor. IBM Watson Healthcare transitions show the following:

* Cognitive Data Analytics partnering Mayo Clinic, CVSHealth and Memorial Sloan Kettering Cancer Center for applications,
* IBM’s Watson’**s** framework learns, connects, and stores the data, while MSK’s data analytics train the computer,
* Other Watson Healthpartners include: Medtronic: Predicting hypoglycemic episodes in diabetic patients nearly three hours before its onset, preventing devastating seizures.
* Merge Healthcare ‘smedical imaging management platform
* Apple: Storing and analyzing ResearchKit data.
* Johnson & Johnson**:** Analyzing scientific papers to find new connections for drug development.
* Under Armour: Powering a “Cognitive Coaching System” that provides athletes coaching around sleep, fitness, activity and nutrition

Comparable “Cognitive Computing” transitions have also been made by Facebook and Amazon. In 2018 Amazon acquired Pillpack (founded 2013) the US mail-order pharmacy for $1 billion. This followed its partnership agreement with prodigiously wealthy Berkshire Hathaway and J.P. Morgan financial platforms.

However, Google (parent company Alphabet) in 2013 began assembling the largest artificial intelligence (AI) laboratory in existence. Acquisitions involved military robotics firm Boston Dynamics, thermostat maker Nest and cutting-edge London (UK) AI firm DeepMind. These were added to smaller purchases of Bot & Dolly, Meka Robotics, Holomni, Redwood Robotics and Schaft, and another AI startup, DNN research. It also hired Geoffrey Hinton to locate at Google Brain 2’s Vector Institute at Toronto University. Hinton is a British computer scientist who is rated the world's leading expert on neural networks (Cadwalladr, 2014). Regarding DeepMind, especially, it was first acquired for the apparently mundane purpose of energy control in Google’s voracious electricity-consuming data centres. However, building on Google’s gargantuan “Big Data” sets for advertising and market analysis, it also crosses over into design of healthcare (medical safety) apps, where it has acquired access to the UK’s NHS patient database as an artificial intelligence (AI) tool. This evolved as a by-product of the firm’s “gaming” capabilities first valued by its founders. In March 2016 DeepMind defeated legendary **Go** player Lee Se-dol in an historic AI victory. Even DeepMind Health is just one of three substantial health-care acquisitions Alphabet is making. It also owns Verily, which creates medical device software, and Calico, which is trying to stretch human lifespans. A project involving London’s Moorfields Eye Hospital and DeepMind aimed to see if AI could perform scans better than opthalmologists analysing optical coherence tomography (OCT), which investigates bleeding and leakage into the retina and allows diagnosis of the most common causes of blindness. In mid-2018, the project was announced to have achieved “impressive” results in outperforming diagnosticians in fulfilling this aim.

So, in summary, our three vignettes, by no means scientific but suggestive of tendencies in global-local co-presencing among local clusters and global cluster-platforms containing giant “flagship” acquisition vehicles capable of transforming corporate and cluster profiles, show the following. First, a new firm at scale in a new industry representing a revolutionary organizational outlook displays some Fordist and some strong cluster tendencies. Thus “early” cluster evolution for Tesla depended on a mix of “earlier” cluster legacies with many “cluster-to-cluster “ spatial interactions between Silicon Valley and US Midwest parts suppliers plus small numbers of global specialists. By its “teenage” phase it was designing its own supplier cluster in Silicon Valley and constructing a Fordist battery “gigafactory” in the Nevada desert. Flowline production was already customised with internal and external planning software fuelled by cloud-facilitated machine-learning AI and robotics. The Tesla set-up is cognate with a “Machine-Learning Region” of a type familiar elsewhere in Silicon Valley’s “cluster-platform” as an Entrepreneurial Regional Innovation System (ERIS; Cooke, 2001). Darktrace’s evolution occurred from the “developed” Cambridge (UK) ICT cluster that had transmuted into a systems and software “entrepreneurial ecosystem” with endogeneity alongside other multi-scalar endogenous and incoming ecosystems of biotechnology, cleantech and AI. Thus it was spun-out of Autonomy the Cambridge data-miner that Hewlett Packard first acquired then sold to nearby UK legacy software integrator MicroFocus. The latter performs Big Data Analytics of a kind that deep learning also involves but Darktrace relies substantially upon machine learning to “learn” how to defeat hackers through EIS. As it currently remains independent and focused strictly upon cybersecurity it is presently part of that Cambridge ecosystem servicing a growing, global customer-base. Finally, DeepMind based in London and initially acquired to manage Google’s energy requirements using AI now interacts with Cambridge-based cleantech research programmes while focusing more strategically on the Big Data analytics associated with its involvement in Google’s healthcare mission. Here and especially in Canada research networks coupled to UK deep learning AI traditions have been partnered as follows. In DeepMind’s case, it runs a network of AI-presences in Silicon Valley and Canada (Google Brain 1 in Montreal’s Institute for Learning Algorithms – MILA; Google Brain 2 AI at the Vector Institute, University of Toronto) and, in 2018, at Edmonton’s, University of Alberta AI facility. Each point is part of DeepMind’s/Google’s “mature” cluster incumbent spawning new AI talent and research “hubs”, having grown to huge corporate scale. These exemplify the DeepMind focus on Deep Learning “Regions”

**2. Clusters: “Was I the future once?"**

**2.1 How do firm, local and global spillovers assist innovation?**

Among cluster advantages widely proposed in the research literature are that:

1. Looser groupings of firms in clusters have better, more efficient knowledge transfer than stand-alone hierarchical corporations.
2. Clusters (e.g. Silicon Valley) combine higher turnover of scientists and engineers with extraordinary openness about technical information.
3. Clusters kill-off unproductive projects through insolvencies while large firms have weak mechanisms for ceasing them.

Successful clusters may attract outside firms and foreign direct investors who perceive benefits from being in a differentiating, leading-edge business location. Foremost also are the *international* processes, networks and knowledge flows that underpin the successful cluster or growing and diversifying “cluster-platform” as with Cambridge, which combines ICT, systems, AI, biotechnology and cleantech. Such progression into “related variety” is an evolutionary process whereby “ahead of the curve” research-based knowledge stimulates Jacobian “urbanisation economies” by mutating from earlier to later innovative knowledge combinations. These, as in the case of ICT, may become general purpose technologies (GPT) as they migrate into biotechnology, systems design applications (e.g. financial “fintech” algorithms, cybersecuriry applications, machine learning and artificial intelligence [AI]) and Cleantech). Each of these “revealed related varieties” have occurred in Cambridge (UK) Silicon Valley and Israel by comparable but not exact knowledge processing and innovation mutations (Grossman & Helpman, 1991; Cooke, 2008; Neffke et al., 2012).

Innovation and growth of the kind displayed in cluster-platforms like those just mentioned are based on rapid, adaptive system-like practices to generate and attract market demand at the global scale. Accordingly the interesting and important puzzle is how this happens. Many of the early claims made for clusters by Porter (1998) were that efficiencies derived from local knowledge interaction and lowered inter-firm transaction costs. However as single clusters – such as that of the initial ICT hardware expertise in California or in microcosm at Cambridge and in Israel at Herzliah - mutated into more diverse entities, notably: “systems” design involving software, engineering design, machine learning, deep learning, algorithm design and artificial intelligence (AI); healthcare design and biotechnology; and clean technology (“cleantech”) a platform of multiple, “crossover” technology interfaces occurred by “spillovers”. This emergent complex of clusters with their own and other complementary cognitive and technological potentials formed what we call a “cluster-platform” (Cooke, 2008). This takes a specific meaning of “platform” metaphorically comprising “planks” that give strength to different but related elements on which may be mounted upon it. This is different from the more specialised idea of a “technology platform” such as, for example, a smartphone Appstore. Here the variety of applications is specialised at the App-level but diversified at the device level. A cluster-platform derives its strength from the option to facilitate the diversification and integration not the separation of platform content. Such crossover potentiality is now the leading and most likely source of value-creating innovation of wide interest to global markets. Integrated mobility systems associated with driverless vehicles, the “Internet of Things” (and/or “Everything”), remote management in farming, forestry, mining and energy, robotized social and healthcare and AI-enhanced clerical, linguistic, financial, legal, administrative and retail service automation in civilian user-spheres and cyberwarfare with drones, signal intelligence (SIGINT) and weaponisation in the military are only some of the system designs of near-future global markets.

Cluster-platforms with digital crossover capabilities as in the above are extremely scarce. In the US there is Silicon Valley, the global cluster-platform leader, then lesser platforms such as New York, Boston and Washington DC (Cooke, 2017). Elsewhere, the UK has Cambridge as a small-scale clone of Silicon Valley but with comparable crossover capabilities, with cyberwarfare SIGINT AI in Cheltenham (GCHQ) and London (Turing Institute, DeepMind and, for genomics, the Crick Institute). We also see Canadian cities like Montreal, Toronto and Edmonton as players while Israel has pieces of all the four main applications (ICT, systems design, biotech and cleantech) and high-level algorithm theory but especially cyberwarfare capabilities. Three key features are crucial here. First, in high-tech it is essential that research is both world-class and within that category, high-grade. This means the knowledge flows of cognitive raw material are at the leading edge of problem definition and suitable teams of researchers exist in dedicated research centres capable of solving problems early on, and preferably, first. Second, the presence of global corporations with specific needs mean that long-term preferred knowledge suppliers have access to needed financial resources that also foster evolving research capabilities. Third, internationalisation involves not just UK global corporate clients but foreign ones for whom the world market is highly competitive. ARM is an excellent case of a Cambridge firm that started in hardware, making Acorn computers in the 1980s-1990s but was able to access software design capabilities from private, local firms (e.g. Cambridge Consultants, PA Consulting) and develop the “fabless” remote systems aspect of its targeted business. Learning from Silicon Valley’s “reduced instruction set chip” (RISC) chip architecture, ARM became expert in learning of Asian silicon “foundries” where “fabless” designs could be realised. Flagship clients like Dell, Hewlett-Packard and Apple later contracted to Taiwanese “foundry” suppliers. These swiftly networked to their transplants (e.g. Foxconn) on the Chinese mainland that then discovered the network advantages of this model. It aggregated excellence at each point of the network. The ARM designs were instantly transferred electronically to the systems integrator (e.g. Mediatek of Taiwan), the logistics worked on a 98/2 schedule. This meant 98% of any chip consignment was delivered in maximum two days for assembly. Taiwanese transplant Foxconn and others met “flagship” quality and reliability standards. Accordingly, Apple’s Silicon Valley neighbour and leading chip designer-producer Intel was until recently deemed too slow by comparison (Isaacson, 2014).

**2.2 Do local spillovers complement or conflict with each other?**

In the exemplars under inspection in this chapter, with their, on the one hand, multiscalar co-presencing with “superclusters” in Asia or Silicon Valley while, on the other hand ready for “entrepreneurial ecosystem” interchanges among local cluster specialities, both kinds of spillovers, in general, benefit from local and global externalities. Regarding logistics efficiencies, global delivery scheduling can be superior in “superclusters” where incoming and outgoing air or sea transportation can be much more sophisticated than in the cluster home-base. Contrastingly, the advanced knowledge content of talent and networks in the home-base cluster can be a world kingpin. Thus Cambridge has attracted major regional R&D headquarters of Microsoft, Amazon and Apple in ICT and AstraZeneca in pharmaceuticals from metropolitan locations to a rural university setting, albeit with an R1 research university capability of genuine world class. By example, 2018 Nobel Laureate for Chemistry, Sir Greg Winter, helped found Cambridge Antibody Technology (CAT) as a start-up, later acquired by AstraZeneca from his base in Cambridge’s Molecular Microbiology Research Laboratory (MMRL) received the prize for his discovery of ways to transform human antibodies into anti-cancer therapeutics.

It is actually extremely difficult to marshall evidence that local spillovers might conflict with those that complement others available in the cluster ecosystem. There must be some evidence of rivalrous practices but the “learned psychology” of networking which is inculcated among researchers and entrepreneurs through the Cambridge Network or St John’s Incubator and other (e.g. Silicon Valley or San Diego CONNECT ecosystems) agencies mean inter-firm progress, including knowledge exchange, is habitually communicated among incumbents.

**2.3 Does the organizational form of the cluster influence its internationalisation?**

The cluster-platform form that has arisen in these distinctive but comparable combinations gives a double boost to entrepreneurship. First, excellence attracts excellence from related ecosystems and secondly, such capability attracts attention from knowledgeable counterparts in superclusters elsewhere. This can be demonstrated over and over again in the Cambridge, the Be’er Sheva and Silicon Valley clusters where one of two things occurs. Either a firm like London’s DeepMind in AI grows exponentially as discussed or it attracts Google and the like, that acquires the firm and makes it its European AI R&D headquarters, then its global deep learning “hub”. This also occurred with AstraZeneca and Amazon, following Microsoft’s experience with locating its R&D HQ for Europe in Cambridge many years earlier. Or, in Be’er Sheva, a military capability gives entrepreneurs leaving the IDF military opportunities to commercialise SIGINT knowledge. Also when the Israeli government assisted the Negev region to establish an Advanced Technology Park, Deutsche Telekom, IBM, Oracle, Lockheed Martin, EMC and PayPal soon announced they were locating upon it to enhance their cybersecurity capabilities. Silicon Valley has all these global R&D divisions located, on site, many having started decades ago as start-up companies like Apple, Google, Oracle, or in-migrant firms like Microsoft and IBM. So it is clear that this is both an agency and structure process in which individual scientists, technologists and entrepreneurs are institutionally embedded in a variable geometry of collective interactions and relationships with an organised ecosystem of innovation and entrepreneurship support institutions. It is not a directly public or managed bureaucracy. It is an innovation system in which there are cluster ecosystems focused upon evolving, distinctive, yet related specialisms. Accordingly it is what the innovation systems literature differentiates into an entrepreneurial regional innovation system (ERIS) not an institutional or public one (IRIS; Cooke. 2001). But no individual can function to develop innovative knowledge new to the market without institutional (formal and informal) collaboration or cooperation with appropriate actors, agencies, or other institutions.

**3. Watched Over By Machines of Learning Grace (**apologies to R. Brautigan**)**

**3.1 Can firm, local or regional strategies assist internationalisation for knowledge sourcing?**

We see from the Cambridge and Silicon Valley (although not the Israeli) cases that little public sector investment goes into direct support of the cluster-platform. It is mostly private or “associative” initiative that manages the Cambridge Phenomenon II or maybe III nowadays. We explore elements of that model of development. We conclude at the mid-point of this article that there is a new and important role for government concerning “digital tech”, new metropolitan innovation hubs for healthcare and AI (London Knowledge Quarter, Toronto-MARS), social media, “Big Data” in public data sources, like healthcare and security, and privacy. These are arguably more important than old-style supply-side policies of the past. This is not least because some of the largest sources of “Big Data” that “digital tech” needs to exploit to make a profit relies on accessing prodigious databanks of public data. Google’s acquisition of DeepMind makes that abundantly clear as does the FAGAMi interest in healthcare for AI data exploitation.

Firm strategies are most important with the cluster perspective playing a comparatively small part in the background “noise” of the cluster. Thus Cambridge’s globally successful ARM systems (SoC; system-on–a-chip) design company had no doubt about accepting Japanese investor SoftBank’s acquisition even though many government and business commentators bemoaned the loss of the UK’s ICT “jewel in the crown”. Similarly data-miner Autonomy welcomed Hewlett Packard’s $8 billion offer to acquire it in 2011. As CAT had done when faced with acquisition by AstraZeneca. These may not have been strategic decisions on the part of the local incumbents, it may be more accurate to call them “opportunistic”.

As we have seen, our exemplar Cambridge is the UK and Europe’s most dynamic high tech research, talent and entrepreneurial “cluster platform” location. It combines at least four distinctive sub-cluster “ecosystems”. The latest review of high-tech performance by the Cambridge cluster reveals, once again, that there is almost no role from the public sector in directly subsidising the Cambridge Phenomenon. Cambridge ranks in the top UK hotspots for growth of its digital economy and the role of the public sector in this has been minimal, The Tech Nation 2016 report by Tech City UK and Nesta (2016) shows Cambridge as a thriving digital technology cluster based on incomes, density of businesses in the segment, international collaboration and economic payback. The report says turnover of digital tech businesses in Cambridge grew 46 per cent between 2010 and 2014.

Other key findings for Cambridge were:

* Average income in digital tech Industries of £47,194
* Digital Gross Value Added at £649 million represents growth of 12 per cent 2010-14
* Digital density (digital businesses as a percentage of total businesses) at 21 per cent
* Turnover growth for the sector of 46 per cent 2010-14

Since the Cambridge Phenomenon began being written about in the 1980s, technology leadership has moved from hardware and computers to the then emergent software and systems design of smartphones and the Internet as part of the prodigious digital tech sector (SQW, 1985; 1998). Firms like ARM (acquired 2016 by SoftBank of Japan) and CSR (acquired 2015 by Qualcomm of USA) became world leaders in the digital systems design platform with Cambridge at its epicentre. Global “*flagship*” firms like Apple and Samsung source 98% of their smartphone chip designs from these two Cambridge firms. Asian sub-contractors and silicon foundries also use such designs in their supplies to US desktop PC firms in decline, like Dell and Hewlett Packard with rising firms like Huawei, ZTE and HCT evolving their systems too. Key digital sectors in Cambridge compared to the UK were in 2016 shown to be the “Internet of Things” (ARM), “Internet of Everything” (CSR) and connected devices, enterprise software (ERP; former Autonomy and Hewlett Packard Enterprise, now MicroFocus) and cloud computing, apps and software development, data management and analytics advanced research from *inter alia* the Alan Turing Institute; GCHQ; Intel and others.

Feeding at fifty miles distance into Cambridge’s science infrastructure, and nominally throughout the UK, is London’s Knowledge Quarter (KQ) a 2014 partnership of 35 large and small research, science, cultural and media organisations located in the Kings Cross, Euston and Bloomsbury areas, including the Wellcome Trust, University College London, Google, the Connected Digital Economy Catapult, The Guardian newspaper, the Aga Khan University, the British Library, University of the Arts, the British Museum, The Francis Crick Institute and Alan Turing Institute in a platform of major research institutions and universities. Its goal is to use the power of this concentration of world-class organisations to spur productive, sustainable and inclusive economic development.  Its work will focus on knowledge exchange and collaboration, including partnership projects between organisations; partnerships and cross-sector initiatives leading to long-term investment and economic growth; improvements to local infrastructure and transport that will benefit employees and visitors to the area; and strengthened alliances with local communities. “Catapult” centres are the UK’s innovation hubs for Digital Tech; Cell & Gene Therapy; Offshore Renewable Energy; and others in Transport Systems, Medical Diagnostics, and Satellite Applications.

**3.2 In what ways can policy help internationalisation of clusters?**

It is clear that in corporate political economies like some Scandinavian countries and Germany or perhaps France politicians believe in a partnership policy model and a more or less formalised national and even sub-national industrial strategy to assist firms to create markets in emerging markets and their cluster concentrations. But in liberal market political economies, the role of the public sector is completely different from the role of subsidiser and enterprise support or even trade and investment agency in the space economy of today. Intangible assets and data ownership management within ethical frameworks is much more important than making grants available for firms in the burgeoning “Big Data” sector in which many new Cambridge and other UK locations now house expertise in such activities as cybersecurity and big data analytics. Thus the kind of Cambridge Phenomenon evolution of public policy for digital-tech firms is shown in the following. It may be more directly partnership with the Defence Department than the Economy Department in the age of the digital tech entrepreneur.

An early insight into the translation of Military Cybersecurity into a profitable technology platform was provided by Senor & Singer (2009). They showed Israel had more venture capital investment per person than anywhere in the world and the largest number of NASDAQ-listed companies (63) after the US and China. So, in 2010, the Israeli Army (Israel Defence Force, IDF) signals intelligence (SIGINT) Unit 8200 alumni decided formally to offer their expertise to other young Israeli entrepreneurs. The result was the 8200 entrepreneurship and innovation support programme (EISP), a five-month high-tech incubator in which Unit 8200 alumni volunteer to mentor early-stage startups. Between 2010 and 2013, 22 received funding totalling $21m (£13.5m) and employ 200 people, joining the 230,000 employees of Israel's 5,000 tech companies that earn $25bn a year – a quarter of Israel's total exports.

Historically, the public sector has had traditional conventions and rules against exploiting taxpayer funds for risk-investments. But where funding is strategic (and enormous) as in defence and healthcare, this risk-fear is lower. With the threat of Islamist-inspired jihadi terrorism at home and abroad, the strongest source for public innovation today is from spying. As we note below, this means Big Surveillance Data for Cybersecurity, especially as evolved over time in Unit 8200, NSA & GCHQ. Derived from the “dark web” skills obtained over decades by SIGINT that USA, UK and Israeli exporters of cyber security products find in demand, are the following. They include algorithms designed to protect companies, banks, governments and – since 9/11, 7/7, Madrid, Mumbai, Paris, Brussels and Nice – citizens far away from the Middle East war zones -- from the growing “dark web” of hackers, fraudsters, snoopers and terrorists. Indirectly government interacts less in Silicon Valley where philanthropy, charity, and social infrastructure often substitute for public action where it has failed. But, it is also clear government largesse in “digital tech” has created excessive wealth among its apps “entrepreneurial ecosystem” and inequality for those not getting to ride from their luxury San Francisco apartments by Googlebus (Rushkoff, 2016).

**4. Conclusions: Is embeddedness in local and global networks supportive of Radical innovations?**

To summarise what has been written concerning the internationalisation of clusters there are three main conclusions. Two are obvious from the text, one is less so and concerns a nagging doubt about clusters but more about the so-called business dynamics of “high-tech” start-ups. The first two conclusions are, first, that – predictably – the landscape is changing. Large firms in “unevenly developed” Quaternary or 4.0 Economy clusters that have grown to enormous size, notably Silicon Valley’s Facebook and Google, Apple and Oracle are prodigiously influential over the world of both mundane but honourable (NHS) and vibrant (Tesla) Big Data exploiting clients. Our Tesla vignette showed a relatively large 2003 “start-up” now implementing “gigafactory” plans for batteries and curating older cluster sub-contractors in the US Midwest to assemble on its proposed Tesla Supplier Park. Amazon, which also curates prodigious numbers of global suppliers, operates huge isolated “chaos storage” fulfillment centres at infrastructure geonodes for swift delivery. Apple, effectively, market-manages China’s supplier “superclusters” centred on million employee Foxconn gigafactories in Shenzhen, Chengdu and elsewhere in China. Google is spawning AI “hubs” in cool climate locations that create talent but also keep data centre energy costs down. Moreover it and Facebook have begun designing “company towns” in their own backyards (Willow Campus on Menlo Park for Facebook and Quayside for Google in Toronto). These are vulnerable to popular protest about tax avoidance, democratic deficits and growing protectionism in key markets.

Second, so probably the excesses of some of the aforementioned polarising targets will – like the banks that transgressed so egregiously before (and after) the Great Crash in 2008 – be re-regulated. And if the bank experience of the aftermath of the global financial crash is an indicator, the trillion-dollar social media giants will continue to find profitable means to outfox the regulators. The symbiotic relationship between “open innovation” among local cluster AI “unicorns” and others in 4.0 economic demand will likely prevail. The unknown effects of cloud-based AI plus robotics upon such “entrepreneurial ecosystems” are awaited. But their implications for “hollowed-out” retail parks and semi-skilled labour more generally do not seem especially propitious.

Finally, third, if social media behemoths do “hollow-out” their own as well as their clients’ workforces, the past has often shown the SME sector taking up the slack. Except that the latest evidence suggests the contrary. The post-2000 decline in US high-growth young businesses in key innovative sectors like high tech suggests there has been a decline in transformational entrepreneurs in this sector. Why this decline has occurred is an open question (Foster et al, 2006; Davis & Haltwanger, 2014; Decker et al, 2014; 2016a; 2016b). In the post-2000 period, high tech includes fewer young firms, and the young firms that are present are less likely to have high growth (Hecker, 2005; Hurst & Pugsley, 2012; Hathaway & Litan, 2014). This period of decline in high-growth entrepreneurship in high tech coincides with the decline in aggregate productivity growth in the high tech sectors of the economy as documented by Fernald (2014). Given the important role high-growth young businesses have played historically in the US, especially in sectors like high tech, understanding the causes and consequences of this decline should be a high priority for future research. For some time the sector has been buoyant in UK and elsewhere in Europe but technological job-decline has been registered in China and elsewhere in Asia. Now recent evidence suggests an entrepreneurship plateau dipped down in 2017 in the UK and declined even earlier in Belgium (Roper et al, 2018; Bijners & Konings, 2017). These may be “blips” but if not they may represent a “perfect storm” of unevenly developing “heavy weather”.

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